PHOSPHINE FUMIGATIONS IN SILO BINS

F. B. BOLAND

State Wheat Board, P.O. Box 136, Toowoomba, Queensland, Australia

ABSTRACT

Wheat in tall, sealed silo bins (2,800 capacity each) was first fumigated commercially using phosphine under slow forced recirculation in 1979 in Queensland, Australia. The phosphine-generating formulation was applied to the grain surface. In most cases existing infestation was eliminated and the grain subsequently stored insect-free. The two instances where infestation was detected after treatment may have been caused by insects entering after the bins had been unsealed.

Trials were carried out using enhanced natural convection as an alternative to forced recirculation, thus avoiding possible explosion hazard through use of fans with phosphine. A large external duct, 'thermosiphon' was rigged between the bin base and apex. This was painted black to enhance the heating of the duct by the sun. The convection so produced gave good distribution of phosphine within five (5) days of application, compared with fifteen (15) days or more without the duct.

Both the forced recirculation system and the thermosiphon overcame the problems of the poor dispersion of phosphine, usually encountered in tall bins after surface application of the formulation.

USE OF PHOSPHINE

Phosphine has been widely used as a grain fumigant in Queensland for many years. In a variety of situations, it is the fumigant of preference, being cheap and easy to apply, readily removed when required by ventilation and leaving little residue on the grain. Until recently, grain stored in large silo bins was routinely treated by adding aluminium phosphide tablets to the grain stream as it was conveyed to or entered the storage bin. The phosphine was generated from the tablets at many points in the bulk. In theory, this created an even concentration phosphine throughout the storage. In practice, this was not necessarily so (Banks and Annis, in press).

This paper details some trials carried out by the State Wheat Board in Queensland to improve the distribution of phosphine obtained in silo bins compared with that given by admixture of tablets during loading and to develop ways of fumigating grain in silo bins with phosphine without the need for turning or other grain movement. It was also important to avoid the mixing of the spent preparation residues with the grain. These residues may contain appreciable quantites of unreleased phosphine and can be objectionable to workers handling grain treated by direct admixture.

The experiments described below both entail some form of recirculation to distribute phosphine through the grain mass. The phosphine was released from preparations laid on the grain surface. It was recognized that, with this form of application, natural convection is often inadequate to distribute the phosphine in tall, narrow bins (Banks and Annis, in press), but otherwise it has several advantages over admixture. These include speed of application and the ability to remove spent preparations without contaminating the grain.

The first forced recirculation treatments with phosphine were carried out in late 1979. At the time we were unaware that a very similar system was also under trial in the U.S.A. (Cook, 1980).

TREATMENTS UNDER FORCED RECIRCULATION

Methods

Treatments were carried out in concrete silo bins of 12.2 m. diameter with 29 m. high cylindrical walls, a concrete conical roof and flat base. The bins had a nominal capacity of 2,800 tonnes of wheat each. All bins were sealed so that they gave a pressure decay time of greater than 7 mins for 1500-750 Pa. decay when filled and were fitted with appropriate fans and ductwork. A tube (grain 'extractor barrel', 450 mm. diam.) led from an opening in the base of the bin wall to the centre of the bin floor. This was fitted so that an auger could be introduced for unloading, but was used as part of the gas distribution system, in these treatments.

The bins were equipped for recirculation using unslotted PVC drainage tubing (helically wire-reinforced, 50 mm. diam.) as the external duct running from close to the apex of the bin, via a blower Model 3B (Dawn: Melbourne) with 0.4 Kw. motor, to an opening in the blanking plate covering the extractor barrel outlet. The blower produced a recirculation rate of about one air change per day in the bin. The recirulation was carried out drawing the gases downward through the grain mass and returning through the external duct to the headspace.

Nine bins, containing 25,100 tonnes of wheat in total, were treated with 'Phostoxin' tablets at a rate equivalent to 0.5 gPH_3/t^{-1}. The peak of the grain bulk was levelled off. The tablets were laid in a polyethylene sheet on the level area in such a way that no tablets touched. After laying out the tablets, the apex hatch was sealed and recirulation commenced immediately.

Results

Phosphine concentration

Phosphine concentrations were measured by Drager tube at four points in the bin: in the headspace and at three points around the base of each bin (Table 1). Recirculation was discontinued after five (5) days. Phosphine concentrations were below 0.3 ppm. at all points sampled after about two months from dosing.

TABLE 1

Typical Phosphine Concentration (ppm) in a Silo Bin Under Forced Recirculation

Sampling Point	After 3-5 Days	After 11 Days
Headspace	525	100
At base by inlet for recirculation duct	475	100
At 90^{o} to this point at base	150	100
At 180^{o} to this point at base	100	100

Effectiveness of the treatment

Insects (*Tribolium castaneum* Herbst) were detected in two of the nine treated bins 4½ months after dosing. All were known to be infested before treatment. The bins had been unsealed and inspected at 2-3 week intervals two months after dosing. There is a significant chance that the insects entered the bin through the unsealed hatches after the treatment. Their presence is thus not evidence that the treatment was unsuccessful.

All bins were retreated by the same method after five months and the three bins still containing grain were again treated after a further five months. No insects were detected on outloading nor reported by consignees receiving wheat from the treated bin.

Further use of forced recirculation

The technique was considered commercially successful, despite the occurrence of infestation on two occasions after treatment. In the 1980/81 season it was used in a further three bins. A second treatment was required in one of these bins. *Cryptolestes spp* were noted at the grain surface after more than eight months storage. Use of forced recirculation of phosphine has now been discontinued because of fears of possible explosive hazard triggered by the reduced pressures created in the recirculation fans. (Monro 1969, p.251 specifically recommends that phosphine not be subjected to recirculation).

It is hoped that the studies on phosphine explosibility currently underway in Australia (Green et al., in press) may permit development of procedures for recirculation of phosphine which are safe and thus clearing the way for use of the technique again.

THERMOSIPHON DISTRIBUTION OF PHOSPHINE

Two trials have been carried out recently to determine if natural convection can be used instead of forced distribution to disperse phosphine in tall silo bins after surface application. The use of natural convection avoids the possible explosion hazards created by fans, noted above, since the pressure differences involved are very small and are created gradually, not suddenly, as with the start-up of a fan.

Methods

The trials were conducted at Toobeah and Meandarra, Queensland in sealed concrete silo bins similar to those used for forced phosphine recirculation. At both sites, one bin was equipped with an external duct of black-painted galvanized iron (375 mm. diam.) running up the cylindrical wall of the bin. The duct was connected with flexible PVC ducting to the bin at the base through the extractor barrel plate and close to the apex through an inspection hatch. The vertical section of the duct was positioned so as to catch the sun thus heating the gases within the duct and providing gas circulation through the updraught so created. At both sites another similar bin was left unmodified and used as a 'control' bin.

Phosphine was applied as aluminium phosphine tablets (Phostoxin) to the grain surface at a rate of about 0.75 gPH_3/t^{-1} in each bin.

Gas distribution

In the control bins phosphine dispersion was slow. In both cases phosphine reached all parts of the bin sampled only after many days. In the bins equipped with the thermosiphon system, distribution was rapid. Table 2 illustrates the different rate of phosphine dispersion observed in the two types of systems. Banks and Annis (in press) have given average phosphine concentrations observed with the unmodified bin in the Meandarra trial.

TABLE 2.

Time Taken to Reach 100ppm. Phosphine at all Points Sampled

	Unmodified	With Thermosiphon
Toobeah	Not achieved after 19 days	5 days
Meandarra	15 days	5 days

The gas concentration readings showed that, with a thermosiphon system, there was a sufficient rate of circulation to provide a fairly uniform distribution of gas within two days of closing. Without the ductwork phosphine dispersed slowly downward from the surface for many days with very high concentrations (greater than 1000ppm.) maintained in the headspace and low or negligible concentrations towards the base of the bin.

The details of these trials will be presented in full elsewhere.

DISCUSSION

This paper has outlined results of trials with two systems for assisting the distribution of phosphine in tall silo bins. Both appear to be practically successful. The thermosiphon system appears well suited to isolated storage sites where maintenance of machinery may be a problem, and avoids the possible danger from use of fans with phosphine. However, if this danger can be overcome, forced recirculation may also be useful. It is easily regulated and not subject to vagaries of the weather that would influence the natural convection system. It may also achieve an even distribution more rapidly, thus possibly permitting a shorter exposure period.

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